MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EPM4086 – DIGITAL CONTROL SYSTEMS
(RE)

9 MARCH 2019
2.30 p.m – 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Attempt **FOUR** out of **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.
4. Table of Transform Pairs has been included in Appendix.

Question 1

(a) (i) What is sample and hold? [3 marks]

(ii) What are the advantages to have digital controller? [3 marks]

(b) Consider the control system as shown in **Figure Q1a** where $x_1(k)$ is a state variable. Find the output $y(k)$ when the input $r(k)$ is unit step. [8 marks]

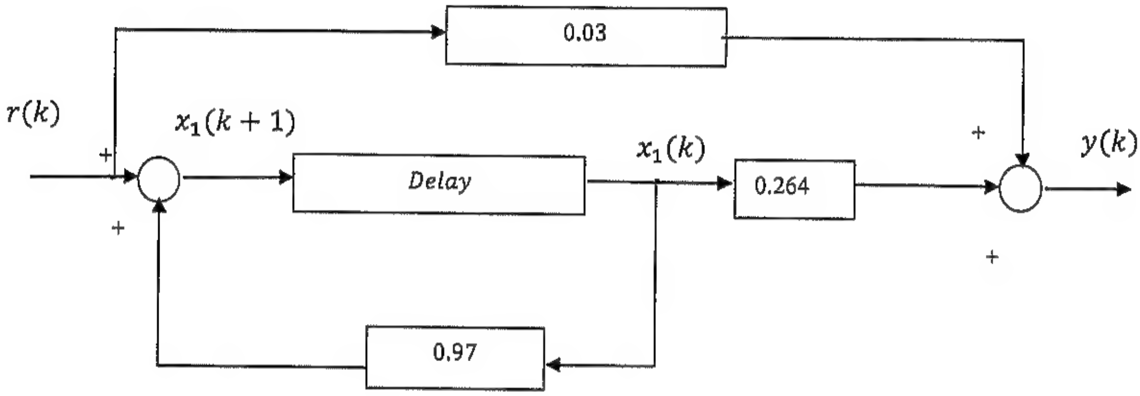

Figure Q1a

(c) For the function $f(k) = (0.6)^k U_s(k) + 0.9k(0.1)^{k-1}U_s(k-1)$, Analyze $F(z)$ using final value theorem. [6 marks]

(d) Given the system as shown in **Figure Q1b**, determine transfer function of $\frac{C(z)}{R(z)}$. [5 marks]

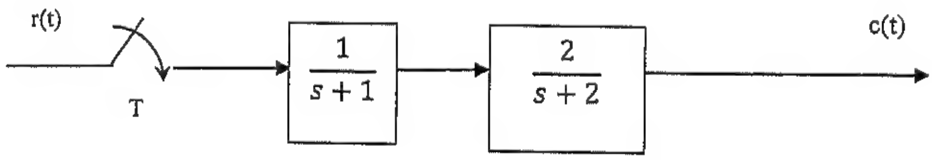

Figure Q1b

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Question 2

(a) In digital control systems, the steps involved in realizing the state diagram and dynamic equations of z-transfer function are termed as *decomposition*. There are three basic types of decomposition: *direct decomposition*, *cascade decomposition*, and *parallel decomposition*. Apply state diagram to show the cascade decomposition. [8 marks]

(b). A linear discrete-time system is described by the following transfer function:

$$\frac{C(z)}{R(z)} = \frac{Z+0.6}{Z^3+2Z^2+Z+0.7}$$

(i) Apply Direct Decomposition method to decompose the transfer function [4 marks]

(ii) Draw the state diagram after apply Direct Decomposition method [3 marks]

(iii) Write the discrete state equation in vector-matrix form after apply Direct Decomposition method [3 marks]

(c) The block diagram of a discrete system is shown in **Figure Q2(c)** with $G_P(s) = \frac{10}{s(s+2)}$. Determine the transfer function of $\frac{C(z)}{R(z)}$ where T=1. [7 marks]

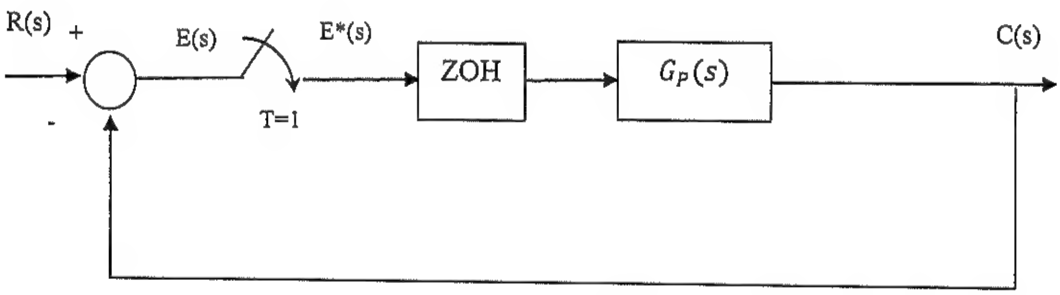

Figure Q2(c)

Continued ...

Question 3

(a) For the Bounded-input-bounded output (BIBO) and zero-input stability, show that the roots of the characteristic equation to be inside the unit circle in the z-plane. [6 marks]

(b) **Figure Q3(b)** shows the block diagram of the servo control system and $D(z) = 1$. Determine the transfer function of the closed loop system with sampling period $T = 0.1$ second. [11 marks]

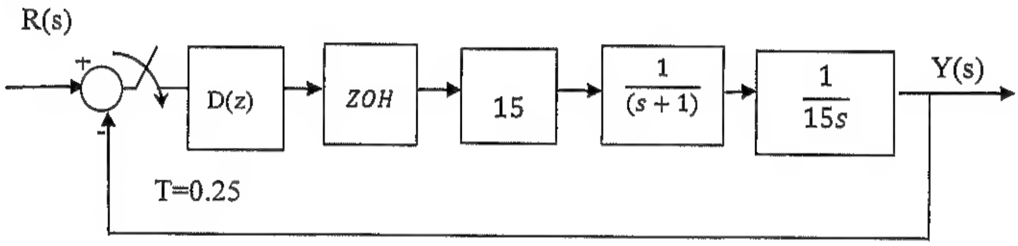

Figure Q3(b)

(c) Consider the characteristic equation of a discrete-time control system given by

$$F(z) = z^3 - 1.5z^2 + 1.75z - 0.6 = 0$$

(i) Transforming z into the r-domain [4 marks]

(ii) Apply Routh Table to check the stability [4 marks]

Continued ...

Question 4

(a) Consider an open loop system, the main objective is to implement state feedback design with deadbeat control.

$$X(k+1) = AX(k) + BU(k)$$
$$Y(k) = CX(k) + DU(k)$$

where $A = \begin{bmatrix} 0 & 1 \\ -0.6 & 1.4 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 0.6 \end{bmatrix}$, $C = [1 \quad 0]$, $D = 0$

Assume the state variable, $x(k)$, is measurable. Design a controller $U(k) = -FX(k) + JR(k)$ such that the closed loop system is to be represented as:-

$$X(k+1) = \tilde{A}X(k) + \tilde{B}U(k)$$
$$Y(k) = \tilde{C}X(k) + \tilde{D}U(k)$$

(Note: $\tilde{A}, \tilde{B}, \tilde{C}, \tilde{D}$ *are the new matrices after adding the controller*)

(i) Determine $\tilde{A}, \tilde{B}, \tilde{C}, \tilde{D}$ [8 marks]

(ii) Select the value of f_1 and f_2 which will lead to a deadbeat performance. [10 marks]

(b) The state model of the closed-loop system is given by

$$\mathbf{x}(k+1) = (\mathbf{A}+\mathbf{BK})\mathbf{x}(k) + \mathbf{Br}(k)$$
$$\mathbf{y}(k) = (\mathbf{C}+\mathbf{DK})\mathbf{x}(k) + \mathbf{Dr}(k)$$

where **x** is $n \times 1$ state vector, **u** is $p \times 1$ input vector, **y** is $q \times 1$ output vector, and **A**, **B**, **C**, ad **D** are real constant matrices of appropriate dimensions, $\mathbf{r}(k)$ is the reference input and **K** is some real constant matrix (feedback matrix/gain matrix). Show schematically the closed-loop system. [7 marks]

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APPENDIX

TABLE OF TRANSFORM PAIRS

Time function $f(t); t > 0$	Laplace Transform $F(s)$	Z-transform $F(z)$, $T =$ Sampling time
$u_s(t)$	$1/s$	$z/(z-1)$
t	$1/s^2$	$Tz/(z-1)^2$
t^2	$2/s^3$	$T^2 z(z+1)/(z-1)^3$
ε^{-at}	$1/(s+a)$	$z/(z-\varepsilon^{-aT})$
$1-\varepsilon^{-at}$	$a/\{s(s+a)\}$	$z(1-\varepsilon^{-aT})/\{(z-1)(z-\varepsilon^{-aT})\}$
$t\varepsilon^{-at}$	$1/(s+a)^2$	$Tz\varepsilon^{-aT}/(z-\varepsilon^{-aT})^2$
$\sin at$	$a/(s^2+a^2)$	$z\sin aT/(z^2-2z\cos aT+1)$
$\cos at$	$s/(s^2+a^2)$	$z(z-\cos aT)/(z^2-2z\cos aT+1)$
$\varepsilon^{-at}\sin bt$	$b/\{(s+a)^2+b^2\}$	$z\varepsilon^{-aT}\sin bT/(z^2-2z\varepsilon^{-aT}\cos bT+\varepsilon^{-2aT})$
$\varepsilon^{-at}\cos bt$	$(s+a)/\{(s+a)^2+b^2\}$	$(z^2-z\varepsilon^{-aT}\cos bT)/(z^2-2z\varepsilon^{-aT}\cos bT+\varepsilon^{-2aT})$

End of Paper